New algorithms for Flavour Tagging at the LHCb experiment

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- Measurements of flavour oscillations and time-dependent CP asymmetries of neutral B mesons require the identification of the flavour of the meson at production (flavour tagging).
- Opposite-side (OS) algorithms exploit the main b → 5 quark production mechanism in pp collisions:
  - production flavour of the signal B is opposite to that of the other B hadron in the event, thus the decay products of the other B hadron can be used for flavour tagging.
- Same-side (SS) algorithms exploit the charge correlation between the two meson flavour and the particles produced in association with the b hadron hijacking.

## Tagging Algorithms

Flavour tagging variables

- **OS algorithms**
  - Muon/Electron
  - Kaon
  - Charm
  - Vertex Charge
- **SS algorithms**
  - Kaon
  - Pion
  - Proton

The function \( \omega(\eta) \) is used to calibrate the mistag probability \( \eta \) to provide an unbiased estimate of the mistag fraction.

### Development of new SS Taggers

#### Tagger training
- The SS taggers apply a set of preselection cuts to select the tagging candidates.
- Combine their geometric and kinematic variables by means a Multi-Variate Analysis (MVA) to choose the best tagging candidate.

#### SS Kaon NN
- SSK NN improves the already available SSK cut-based tagger [7]
- New algorithm optimized with \( B_s \to \phi K^0 \) decays from Run 1 data and simulations [8]
- Based on two Neural Networks (NN) (trained with simulations)
  - NN1 trained to recognize kaons produced in the b quark hadronization
  - NN2 combines the tracks selected by NN1 to assign the tag decision and \( \eta \) (trained with simulation and calibrated with data)

#### SS Pion BDT/Proton BDT (preliminary)
- SSK NN improves the already available SSK cut-based tagger [9]
- First development and use of a SSS tagger
- New algorithm optimized with \( B^0 \to D^- \pi^+ \) data (8 TeV)
- Based on a MVA using a Boost Decision Tree (BDT)
  - BDT trained with data (oscillated events reduced by a cut at \( t < 2.2 \) ps) exploits the charge correlation of the SS tracks with the B decay mode \( (\pi^- B^+ , B^- \pi^+) \)
  - The candidate with the highest BDT output is chosen as best candidate
  - 3rd order polynomial \( \eta(BDT \text{ output}) \) is used to evaluate the predicted mistag

#### SSK results
- Tagging power improved by 50% compared to the previous SS tagger
- SSK NN calibrated also on \( B_s^0 \to B^- K^- \)
- Assume that \( B_s^0 \) and \( B_s^+ \) have the same hadronization process
- \( B_s^0 \to B^+ K^- \) strong decay: the charge of \( B^+ \) determines the flavour of the \( B_s^0 \)

### Physics results

#### Measurement of sin(2β)
- The time-dependent CP asymmetry accesses the \( \beta \) angle of the CKM unitary triangle
  - \( A_{CP}(t) = S \sin(\Delta m t) - C \cos(\Delta m t) \)
  - Use \( B^0 \to D^- \pi^+ \) decays from Run 1 dataset
  - Tagger: OS+SSK NN

#### Measurements of \( \phi_\epsilon \)
- \( \phi_\epsilon \Rightarrow \) CP-violating weak mixing phase of \( B_1 \)
- Use \( B^0 \to J/\psi K^0 K^- \), \( B_s^0 \to J/\psi \pi^- \pi^+ \)
  - \( B_s^0 \to D_s^+ D_s^- \) decays from Run 1 dataset
  - Tagger: OS+SSK NN

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  - 3rd order polynomial \( \eta(BDT \text{ output}) \) is used to evaluate the predicted mistag

#### SSπ and SSp results (preliminary)
- Tagging power improvement of 60% compared to the previous SSS tagger
- SSS and SSp responses can be combined into a single SS tagger response
- Combining SS and OS taggers improves the tagging power by about 45%
- Validation of the performance in a different control channel: \( B^0 \to K^- \pi^+ \)
  - Lower tagging performances (softer \( B p_j \) distribution)
  - Predicted mistag \( \eta \) calibrated

## References

[5] H. Aihara et al., New algorithms for Flavour Tagging at the LHCb experiment. Università degli Studi di Milano Bicocca & INFN.